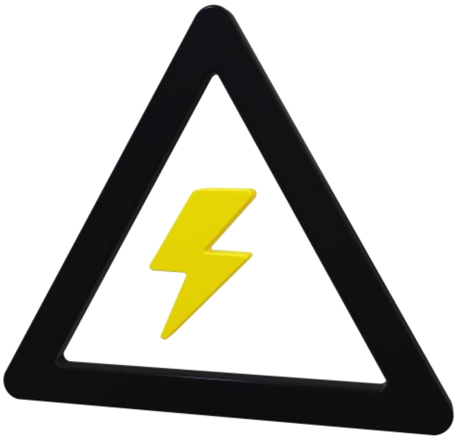

Electronics Course
Session No.1

2020

مسائل محلولة

Eng. Mohamed Numair

www.MohamedNumair.cf

1 **Determine the density of electrons in silicon at T = 300 K (room temperature) and T = 600 K.**

from Book: Example 1.1

Given:

Since for silicon

$$E_g = 1.12\ eV = 1.792 \times 10^{-19}\ J$$

Boltzamn Constant

$$k = 1.38 \times 10^{-23}\ \ J/K$$

Solution

$$for\ T = 300\ K$$

$$n_i = 5.2 \times 10^{15}\ T^{\frac{3}{2}}\ e^{\frac{-E_g}{2kT}}$$

$$n_i = 5.2 \times 10^{15}\ (300)^{\frac{3}{2}}\ e^{\frac{-1.792\times10^{-19}}{2(1.38\times10^{-23})(300)}}$$

$$@\ \mathrm{T} = 300\ \mathrm{K} \Rightarrow\ \ \mathrm{n_i} = 1.08 \times 10^{10}\ \mathrm{electron/cm^3}$$

$$for\ T = 600\ K$$

$$n_i = 5.2 \times 10^{15}\ T^{\frac{3}{2}}\ e^{\frac{-E_g}{2kT}}$$

$$n_i = 5.2 \times 10^{15}\ (600)^{\frac{3}{2}}\ e^{\frac{-1.792\times10^{-19}}{2(1.38\times10^{-23})(600)}}$$

$$@\ \mathrm{T} = 600\ \mathrm{K} \Rightarrow\ \ \mathrm{n_i} = 1.54 \times 10^{15}\ \mathrm{electron/cm^3}$$

And determine the number of holes

Number of holes (p)= number of electrons ($n_i = n$)

$$@\ \mathrm{T} = 300\ \mathrm{K} \Rightarrow\ \ p = 1.08 \times 10^{10}\ \mathrm{hole/cm^3}$$

$$@\ \mathrm{T} = 600\ \mathrm{K} \Rightarrow\ \ p = 1.54 \times 10^{15}\ \mathrm{hole/cm^3}$$

2 **Determine the density of electrons (for a material having bandgap 1.5eV) at T = 300 K (room temperature) and T = 600 K.**

from Book: Exercise

Given:

Since for

$$E_g = 1.5\,eV = 2.4 \times 10^{-19} J$$

Boltzamn Constant

$$k = 1.38 \times 10^{-23}\ J/K$$

Solution

$$for\ T = 300\ K$$

$$n_i = 5.2 \times 10^{15}\, T^{\frac{3}{2}}\, e^{\frac{-E_g}{2kT}}$$

$$n_i = 5.2 \times 10^{15}\, (300)^{\frac{3}{2}}\, e^{\frac{-2.4\times10^{-19}}{2(1.38\times10^{-23})(300)}}$$

$$@\,\mathrm{T} = 300\ \mathrm{K} \Rightarrow\ \ \mathrm{n_i} = \qquad\qquad \mathrm{electron/cm^3}$$

$$for\ T = 600\ K$$

$$n_i = 5.2 \times 10^{15}\, T^{\frac{3}{2}}\, e^{\frac{-E_g}{2kT}}$$

$$n_i = 5.2 \times 10^{15}\, (600)^{\frac{3}{2}}\, e^{\frac{-2.4\times10^{-19}}{2(1.38\times10^{-23})(600)}}$$

$$@\,\mathrm{T} = 600\ \mathrm{K} \Rightarrow\ \ \mathrm{n_i} = \qquad\qquad \mathrm{electron/cm^3}$$

And determine the number of holes

Number of holes (p)= number of electrons $(n_i = n)$

$$@\,\mathrm{T} = 300\ \mathrm{K} \Rightarrow\ \ p = 1.08 \times 10^{10}\ \mathrm{hole/cm^3}$$

$$@\,\mathrm{T} = 600\ \mathrm{K} \Rightarrow\ \ p = 1.54 \times 10^{15}\ \mathrm{hole/cm^3}$$

3 **Why in an extrinsic silicon $np = n_i^2$, How can np remain constant while we add more donor atoms and increase n?**

from Book: Example 1.2

Solution

As in extrinsic silicon, when doped with a Doner (n-type dopant)(Phosph.) this equation $np = n_i^2$

Shows that p must fall below its intrinsic level as more n-type dopants are added

to the crystal. This occurs because many of the new electrons donated by the dopant

with the holes that were created in the intrinsic material."“recombine

$$with\, n - type:\ n \uparrow p \downarrow = n_i^2 (const)$$

And the reverse happened when adding (p-type dopant) (Boron) as holes number increase and electrons number decrease.

$$with\, p - type:\ n \downarrow\ p \uparrow = n_i^2 (const)$$

بالعربي

لأن المعادلة $np = n_i^2$ تقترح انه (عند التطعيم بالفسفور (متبرع الكترونات)) يحدث زيادة في الالكترونات

و في المقابل يقل عدد الفجوات، وهو منطقي حيث ان الالكترونات الحرة ترتبط مرة أخرى بالفجوات وتستقر،

فتغلق الفجوات، فيكون الناتج النهايه ان عدد الفجوات أصبحت اقل مما كانت عليه في السيليكون النقي و

الالكترونات زادت عما كانت عليه في السيليكون النقي

العكس تماماً (زياده الفجوات – نقصان الالكترونات) يحدث عند التطعيم بالبورون (مستقبل لإلكترونات)

4 **Why can we not say that $n + p$ should remain constant?**

from Book: Exercise

Solution

As this will indicate that it's possible for ***n=0*** and ***p=const*** or ***p=0*** and ***n=const**, and that's not the case at all as will always be electrons and holes at the same time, it's just that one of them will be major and the other is minor.*

5 **A piece of crystalline silicon is doped uniformly with phosphorus atoms. The doping density is 10^{16} atoms/cm^3. Determine the electron and hole densities in this material at the room temperature.**

from Book: Example 1.3

Given:

From previous Example 1.1

$$n_i = 1.08 \times 10^{10} \text{electron/cm}^3$$

Doping

$$N_D = 10^{16}\ atoms/cm^3$$

Solution

As for

$$n \cong\ N_D = 10^{16}\ electrons/cm^3$$

And from $np = n_i^2$

$$p = \frac{n_i^2}{n} = \frac{n_i^2}{N_D} = \frac{\left(1.08 \times 10^{10}\right)^2}{10^{16}} = 1.17 \times 10^4 \frac{holes}{cm^3}$$

Note that the hole density has dropped below the intrinsic level by six orders of magnitude. Thus, if a voltage is applied across this piece of silicon, the resulting current predominantly consists of electrons

(Major Carriers: Electrons)

6 **At what doping level does the hole density drop by three orders of magnitude?**
from Book: Exercise

Solution

$10\ magnitudes\ for\ last\ example \qquad p = \frac{10^{10^2}}{10^{16}} = \frac{10^{20}}{10^{16}} = 10^4$

$as\ 4(= 20 - 16)\ so\ it's\ less\ than\ 10\ by\ 6\ orders$

for 3 orders

We need doping of $N_D = 10^{13}$ *so it will get (20-13 = 7) so it's less by 3 degree.*

7 **Is it possible to use other elements of Fig. 2.2 as semiconductors and dopants?**
from Book: Example 1.4

Solution

Yes, for example, some early diodes and transistors were based on germanium (Ge) rather than silicon. Also, arsenic (As) is another common dopant.

8 **Can carbon be used for this purpose?**
from Book: Exercise

Solution

No as it has it's 4 electrons in the second level which is strongly attached to the nuclus so it's hard to give it enough Eg.

الكربون شبه موصل لكن لا يستخدم لان الكتروناته في المستوى الثاني وهو مرتبط بالنواه وصعب التحرر للالكترونات